5–4 Use of Diamonds for Single Ion Detection

— Real-Time Detection of Ion Impact Position by Fluorescence of Nitrogen Vacancy Centers —

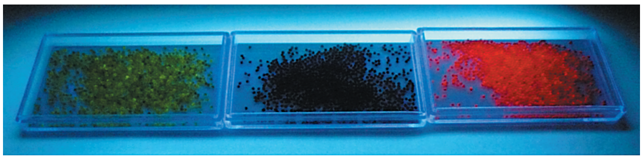

Fig.5-9 Photograph of diamonds irradiated by ultraviolet light
Photographs of diamonds containing dense nitrogen (left), electron-irradiated diamonds (middle), and diamonds containing NV centers after thermal treatment (right). The colors are peculiar to the impurities and defects.

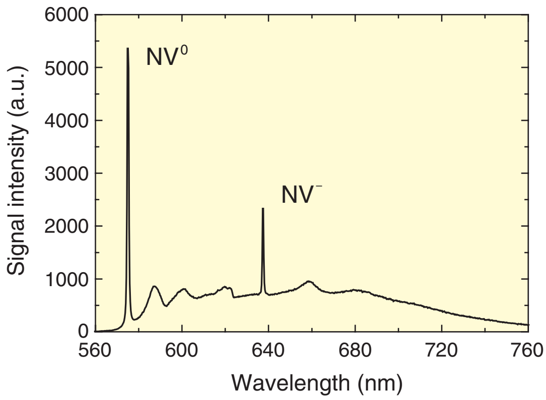

Fig.5-10 Photoluminescence spectrum of created NV center
After electron irradiation and thermal treatment, the diamonds contain electrically neutral NV^0 centers and negatively charged NV^- centers.

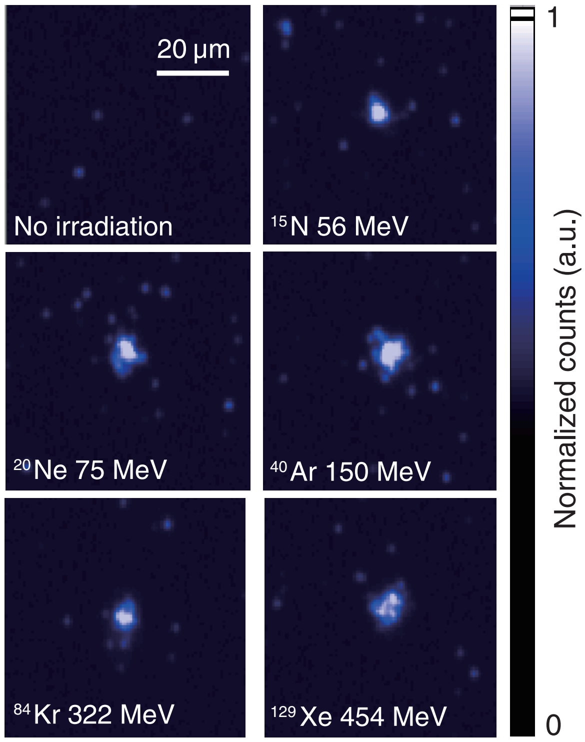

Fig.5-11 CCD images when an ion strikes a diamond
When an ion strikes a diamond containing NV centers, the very weak luminescence light from the ion impact position is successfully detected.

A single ion causes temporary malfunctions and permanent failures in semiconductors, which are called single event effects (SEEs). To use semiconductors in harsh radiation environments such as space, it is necessary to clarify the mechanism of SEEs. This requires a technique for detecting a single ion in real time. The technique of detecting the position of fluorescence induced by a single ion on a luminescent sheet is currently used. Therefore, we are exploring a luminescent sheet having strong fluorescence intensity capable of detecting a single ion. In this study, we focus on the features of nitrogen-vacancy defects (NV centers), which efficiently absorb ultraviolet light and emit high-intensity fluorescence.

First, diamonds containing dense NV centers were created from synthetic diamonds containing dense nitrogen impurities. By irradiating the sample with a 2 MeV electron beam, vacancies were introduced into the diamond by the displacement damage mechanism. After electron irradiation, thermal treatment at 800 °C was performed for 2 h. By combining nitrogen impurities with vacancies, we successfully created a diamond containing dense NV centers (Fig.5-9). Photoluminescence spectrum analysis clearly revealed that electrically neutral NV^0 centers and negatively charged NV^- centers were created (Fig.5-10). As shown in the figure, additional defects other than NV centers were not found. Next, the sample was irradiated with several ions at various energies. A measurement system consisting of a highly sensitive CCD camera and an image intensifier was developed. Using the system, fluorescence was successfully detected in real time (Fig.5-11). The spots are detected in the diamonds containing NV centers, but not in those without NV centers. This result is regarded as demonstrating a fundamental technology for elucidating the mechanism of SEEs that reduce the reliability of semiconductors.

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Reference

Onoda, S. et al., Diamonds Utilized in the Development of Single Ion Detector with High Spatial Resolution, Transactions of the Materials Research Society of Japan, vol.37, no.2, 2012, p.241–244.